

## **Scotland's Eroding Heritage: A Collaborative Response to the Impact of Climate Change**

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### **Scotland's Coastal Heritage**

Scotland is a maritime nation, with a coastline 18,670km long (Angus et al. 2011) and a largely inaccessible mountainous hinterland. Settlement has therefore historically been concentrated on the coast, offering such benefits as proximity to marine resources and materials washed up or exposed on beaches, access to transport and trade routes by boat and, in many locations, the best agricultural land available (The James Hutton Institute 2013). This environment has bequeathed a rich and diverse archaeological resource, concentrated along the coastline and representing all periods, from the Mesolithic to the Second World War. In addition to occupation sites, religious and funerary monuments and defensive structures found at the coast, the importance of the sea and seafaring to the country is eloquently demonstrated by the remains of economic and maritime activity, industry and coastal infrastructure. Sites such as kelp kilns, harbours, coal mines, fishing stations and even the remains of vessels that once plied the waters can be found around the coast, particularly in the firths and sheltered estuaries, which offered protection from the open sea.

## Climate Change and the Historic Environment

### *Climate Change and the Coast*

The evidence for climate warming is unequivocal (IPCC 2013). The most recent studies (CCC 2016a) show that the global climate is undergoing change. Although natural variability in the climate system has a significant impact on weather patterns, there is evidence of an increase in extreme weather events (CCC 2016a: 2). The coast and intertidal zone are uniquely dynamic environments, which are vulnerable to specific manifestations of climate change. Sea levels are, for example, rising at an accelerated rate around the globe, including the UK (CCC 2016a; Jenkins et al. 2009). Despite a history of isostatic uplift in Scotland, the most recent data indicate that this is being outpaced, with the entire Scottish coast now experiencing relative sea level rise (Rennie and Hansom 2010). An increased frequency of floods has been noted in the tide gauge records at several Scottish locations (CCC 2016b: 32).

Despite significant uncertainty regarding future storm events (Woolf and Wolf 2013), there is broad consensus of an increasing trend in the frequency and intensity of storms affecting the British Isles region (Feser et al. 2014; Mölter et al. 2016). Storminess will generate higher waves, overtopping seawalls and causing flooding and erosion. This will differentially impact the coastline, with particular vulnerability in the 21 per cent of the Scottish coast that is 'soft' (such as sand dune or salt marsh) and susceptible to erosion (CCC 2016b: 30). This might manifest, for example, as dune migration or shoreline retreat. The remaining 79 per cent of the coastline, although deemed more resilient to coastal change, may nevertheless be subject to cliff collapse, as well as increased flood risk. Sea surface temperatures have risen globally since the 1970s and continue to rise (Hughes et al. 2017; IPCC 2013). The shallow seas around the UK show clear evidence of warming over recent decades, and temperatures are predicted to rise further (Holt et al. 2010; MCCIP 2017). Further, salinity levels in coastal waters are projected to drop, with the freshwater contribution from higher rainfall increasing river discharges, and are expected to most dramatically impact estuaries and near-coastal regions (Lowe et al. 2009: 69).

Recognizing the potential impacts of climate change on the Scottish coast, national responses include the National Coastal Change Assessment ([www.dynamiccoast.com](http://www.dynamiccoast.com)) and the preparation of Shoreline Management Plans for some stretches of coastline; these plans assess the risk and present a range of management options.

### **The Effects of Climate Change on Heritage**

The projected changes to the climate will have wide implications for infrastructure and society, including the historic environment (Cassar 2005). The coastal zone is particularly vulnerable; Cassar (2005) notes that, while coastal loss has always been an issue, coastal heritage sites are now under significant threat due to climate change. Intertidal sites, submerged twice a day, are especially vulnerable, as the water conditions in the incoming tides are altered. Furthermore, the threat climate change poses to the archaeological resource is magnified by the significance of sites in the coastal zone, which are often of a type unique to their environment (Cassar 2005: 32–35).

The effects of climate change on Scotland's heritage "are wide ranging and potentially devastating" (Historic Scotland 2012: 6). Historic Scotland has responded with the publication of a five-year climate change action plan (2012), which sets targets for mitigating the causes of climate change and lays out a series of actions to prepare the historic environment for its anticipated effects. In response to the threats that coastal processes pose, the SCAPE Trust (Scottish Coastal Archaeology and the Problem of Erosion) at the University of St Andrews was established in 2000, with a remit to research and promote the unique archaeological resources of the Scottish coast, especially areas threatened by erosion.

### **Responding to the Threat: A Staged Approach**

#### *Survey*

The threat posed to heritage by climate change is exacerbated by a lack of baseline information; as highlighted by Cassar (2005: 26), the historic environment is vulnerable to loss without ever having been recorded. In order to address this need on the Scottish coast, a programme of rapid Coastal Zone Assessment Surveys (CZAS) was implemented, with the

stated objective of quantifying the scale of the threat to coastal heritage, developing national and regional priorities and informing decisions about the management of this resource (Historic Scotland 1996: 2–4). From 2000, these surveys were managed by SCAPE, and the original guidelines (Historic Scotland 1996) were updated with further recommendations (Dawson 2008). To date, 29 surveys have been carried out, covering approximately 30 per cent of Scotland's coast, with a particular focus on areas thought to be most vulnerable to coastal processes. In addition to recording each site, the surveys also made an assessment of their vulnerability to erosion and, where deemed appropriate, made recommendations for further work. Of the 12,000 sites recorded up until 2011, around 30 per cent carried recommendations for monitoring or further investigation, a number that far outstripped available resources (Dawson 2010: 3).

### *Analysis and Prioritization*

An analysis of this data was conducted to aid informed decision making (Dawson 2010), which, for the first time, brought parity and consistency to the dataset. Moreover, it assessed the archaeological significance of the sites and their vulnerability to erosion in order to prioritise action. This reduced the number of sites for which further work was recommended based on threat to 940, with 329 deemed to be the most urgent. A series of staged tasks were recommended for each of these sites. The analysis also highlighted the degree of change and destruction at some sites since their respective original surveys. Therefore, the first recommended action at every site was an assessment of its current condition.

In order to address this issue, SCAPE developed the Scotland's Coastal Heritage at Risk Project (SCHARP, [www.ssharp.co.uk](http://www.ssharp.co.uk)). Underpinned by the core ethos of public participation and community involvement, and building upon the Shorewatch project (Fraser et al. 2003), SCHARP aimed to develop partnerships between communities and professionals to address the issue of heritage threatened by coastal processes. The project comprised two main elements: a national, volunteer-focused survey to update records of the priority sites (ShoreUPDATE) and a number of practical projects at threatened and locally-valued sites (ShoreDIG) (Dawson et al. 2017).

*Community Involvement: ShoreUPDATE*

ShoreUPDATE recruited, trained and supported volunteers to revisit the sites recorded by the original surveys, with a particular focus on the highest priorities, as identified in the desk-based analysis, in order to update condition information and ground truth the assessment of priority. This approach brought specific benefits to the project by creating a network of trained coastal stewards: local people know their coast best, can respond quickly after events such as major storms and easily make return visits at different times of year or in different tidal conditions. Not only did this reflect the importance of community action within the historic environment (for example, Scottish Government 2014), it also developed Scotland's heritage management capacity.

ShoreUPDATE was underpinned by an interactive portal, available on the project website as the Sites at Risk Map and as a mobile app. Here, the public can access the CZAS records, colour-coded by priority status, and volunteers can upload condition information and photographs. Significant investment was made into training volunteers, both in using this technology and in surveying coastal archaeological sites.

Project staff moderated the data submitted by volunteers and, in the final year of the project, undertook a review of the prioritised dataset to better reflect the updated observations on condition and threat (Hambly 2017). A number of sites had been destroyed by coastal processes prior to the update surveys, and, for some sites, the impact had been mitigated by investigation or recording to rescue information. The ShoreUPDATE surveys also brought parity and a national perspective to the dataset while refining the assessment of priorities. In addition to contributing to the improved management of coastal archaeological resources and presenting priorities for urgent action in response to the threat from coastal processes, this robust, consistent observational data has significant research potential. The project has identified the most vulnerable sites where the impact of coastal processes will manifest and has created a baseline against which to measure current and future coastal change. By developing a programme of regular monitoring for this network of priority sites,

time series data can be constructed on the impact of coastal processes on heritage sites and on the wider trends of coastal change (Hambly 2017).

### *Community Involvement: ShoreDIG*

Recognizing the need for action at threatened sites, the second element of SCHARP, ShoreDIG, integrated the judgement of significance and threat with local value by undertaking practical projects at community-nominated, high-priority sites. These projects were developed as collaborations between the respective local community and the project team and varied in scale and ambition. They employed a range of strategies as diverse as digital documentation and interpretation (Hambly et al. in prep.) or excavation, relocation and interpretation of a Bronze Age burnt mound (Dawson 2015). Although several of the 14 ShoreDIG projects developed out of ShoreUPDATE surveys of priority sites, some were focused on sites that were either previously unrecorded or under-recorded in both the CZAS datasets and the regional and national Historic Environment Records. This reflects the significant proportion of the reviewed and re-prioritised CZAS sites that were added to our records by the ShoreUPDATE process (Hambly 2017), highlighting the need for repeat surveys of the coast. Given that just 35 per cent of the Scottish coast has been surveyed to date, many further valuable but vulnerable sites will be located on coastlines that are as yet unsurveyed, emphasising the urgent need to extend work into new areas.

### **Case Studies: Intertidal Boat Graveyards**

A salient example of these under-recorded sites is the boat graveyard; although these are few in number, they are particularly significant because of their rarity. Three ShoreDIG projects focused on boat graveyards and comprised both detailed archaeological survey of the physical remains and research to understand their historical context.

A collection of 17 wooden fishing boats lies on the sheltered south shore of Loch Fleet, a tidal basin in East Sutherland (fig. 1). Although this area had been examined through a coastal survey in 2010 (Sneddon et al. 2010), the vessels were first recorded by volunteers from the North of Scotland Archaeological Society (NoSAS), who were undertaking a ShoreUPDATE survey and nominated it to be a ShoreDIG project (Graham and

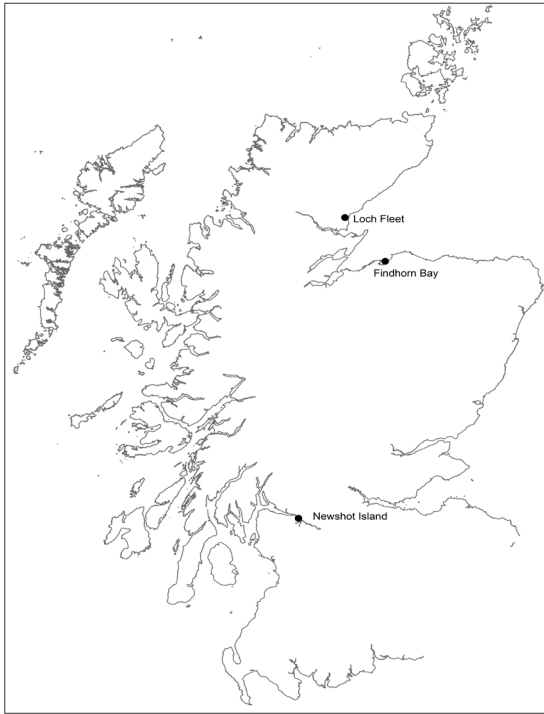


Fig. 1. Location map showing three boat graveyard sites.

Hambly 2017a). Prior to this, the only information held in the regional Historic Environment Record about the site came from a newspaper article that suggested the vessels had formed the fishing fleet of the village of Embo and had been deliberately scuttled and burned following the First World War. Site recording undertaken by members of the local community (with training and guidance from the project team and the Nautical Archaeology Society) included a low-level drone survey, creation of a detailed written and drawn record and wood

species identification. Historical research corrected the erroneous interpretation that linked the site to the First World War. It showed instead that these wooden sailing drifters, known as 'Zulus', had been abandoned at their regular winter safe haven on Loch Fleet in the twentieth century due to their obsolescence in the face of steam power.

Subsequently, a second site was identified by NoSAS in the sheltered tidal basin of Findhorn Bay, Moray, on a stretch of coast that has not yet been subject to a CZA survey (fig. 1). This boat graveyard comprised the remains of at least 30 also unrecorded wooden vessels (fig. 2), aside from a note of a single wreck identified from aerial photography. The fieldwork, again undertaken in partnership with the local





Fig. 2. Aerial view of two vessels in Findhorn Bay boat graveyard (reproduced with permission of Eddie Martin).

community, comprised the same recording techniques (Graham and Hambly 2017b), while research demonstrated the nuanced evolution of the Moray coast herring fishery in the early twentieth century and explained the factors behind the formation of the boat graveyard.

A third intertidal ShoreDIG survey was undertaken at Newshot Island on the bank of the Clyde (fig. 1; Graham and Hambly 2017c), where a brief record had been created by the CZA survey. This boat graveyard consists of two elements: four wooden schooners and a collection of vessels which had formed part of the river's dredging plant, comprising around 50 mud punts, as well as a diving bell barge, thought to be a unique survival. Research undertaken alongside the fieldwork corrected a statement in the original record, which attributed the dumping of the schooners to a wartime bombing raid: the work instead indicated that the boats had been destroyed by a catastrophic fire during renovation of the Kingston Dock in 1914.



Examination of archives also illustrated the history of the dredging vessels and their role in the creation and maintenance of the Clyde Navigation.

These surveys created a record of a rare site type, and, taken together, the Findhorn and Loch Fleet projects illustrate the complex interplay of factors in the local fishing industry at a time of great social and economic change, while the remains at Newshot Island exemplify the central but often overlooked role of the dredging fleet in the history of the Clyde. All three projects either corrected inaccurate information or created new records, and none would have been identified as worthy of further investigation had it not been for the volunteers participating in SCHARP.

It has been suggested (Dawson 2004) that the rarity of such boat graveyards in the records is in part a reflection of the original CZA surveys and the difficulty of locating sites on the foreshore during a rapid survey, when fieldwork is not always timed to coincide with low tides, and in an inherently dynamic environment, where sediments constantly shift. Remains in the intertidal zone have thus, to an extent, fallen between the cracks of archaeological fieldwork: they are not comprehensively captured by coastal surveys, but they are often considered outside the remit of traditional maritime archaeology. Consisting of fragile wooden structures in the intertidal zone, all are inherently vulnerable to a variety of threats. As a result of this work, the boat graveyard at Newshot is being considered for nomination as a Scheduled Ancient Monument or a Historic Marine Protected Area. However, such status confers only legal protection, and this dynamic location is vulnerable to a number of natural and climate-related threats that are common to all coastal environments, in addition to specific risks inherent to their intertidal context. Submerged by seawater twice a day, such remains are also subject to some of the same threats as underwater heritage.

### **Wood Borers and Maritime Heritage**

One of the threats that may increase in the future due to climate change is damage from wood-boring sea creatures. Shipworm has been recognized for hundreds of years as a threat to wooden structures in the maritime environment, causing well-attested damage to dikes in the Netherlands in the eighteenth century (Koopmans 2016). Examples of archaeological sites

damaged by wood borers are found around the world (Grenier et al. 2006; Palma and Santhakumaran 2014). In a review of the role of science in heritage management in the UK, shipworm was identified as a threat to submerged wooden heritage (Williams 2009), and wrecks such as the *Flower of Ugie* and the *Fenna* in the Solent have already been affected (Whitewright and Satchell 2010, 2011). The gravity of the threat posed to submerged heritage is illustrated by recent investigations into shipworm attacks and the evaluation of methods to preserve sites from such attacks (Eriksen and Gregory 2016). Although this is predominantly thought of as a threat to submerged heritage, shipworm have also been found to damage intertidal structures (Borges et al. 2010; Palma and Santhakumaran 2014: 41).

### **Shipworm and Climate Change**

Sabbioni et al. (2012) identified the biological attack of organic materials by insects, fungi and invasive species as a potential impact of climate change on cultural heritage. Previous studies have shown that changing water conditions due to climate change have had an impact on the range and distribution of shipworm species (Borges et al. 2010). Concern over the spread of *Teredo navalis* into new areas of the Baltic Sea and the creatures' potential impact on the area's unique archaeological heritage has prompted studies such as the WreckProtect project to try to predict their future distribution (Björdal et al. 2012). Concerns about damage to infrastructure have prompted an examination of changing conditions in the Rhine-Meuse estuary; such study predicts an upstream expansion of shipworm as a consequence of climate change (Paalvast and van der Velde 2011). Further, it has been suggested that this phenomenon can also be extrapolated to other estuaries in northwest Europe (Paalvast and van der Velde 2011). Furthermore, the inaugural 2007 identification of a warm-water species of shipworm in Portsmouth, which is that species' northernmost known limit, suggests that its northwards expansion may be related to increasing temperatures (Borges 2007: 225). Invasive and more voracious, warm-water species are migrating north and augmenting native species: this movement is facilitated by rising sea temperatures, which have been interpreted as an indicator of climate change (Palma and Santhakumaran 2014: 40).

## Shipworm in Scotland

Studies of the distribution and environmental requirements of shipworm species in European waters (Borges et al. 2014) have exposed the presence of four species of shipworm (*Teredo navalis*, *Nototeredo norvegica*, *Psiloteredo megotara* and *Teredora malleolus*) in the waters around Scotland. The conditions in Scotland are therefore suitable for shipworm populations, although they occur significantly less frequently than they do in areas further south in the North Sea, in the Mediterranean and along other stretches of the Atlantic coast. Furthermore, shipworm damage has been observed on submerged sites in Scottish waters (McCarthy et al. 2015) and on intertidal wooden structures on the Beaulieu Firth (Hale 2004: 193). Scottish waters are clearly a viable environment for at least some shipworm species, although comparison of various species' requirements with current water conditions suggests some may be near the limit of their respective tolerances.

It has been demonstrated that the most important parameters for the distribution and abundance of shipworm populations are temperature and salinity. These vary from species to species, but *Teredo navalis* has a particularly wide tolerance for both, surviving in temperatures of 0–30°C and in salinity ranges of 7–39 PSU (Borges et al. 2014). Optimal temperature conditions for populations to expand, however, are thought to be between 15–25°C; a minimum of 11–12°C is required for spawning. Temperature also influences boring activity, which decreases below 10°C and ceases at 5°C. However, populations can survive temperatures approaching freezing by hibernating. Likewise, minimum salinity levels are required for boring; however, when levels drop below nine PSU, the boring tubes can be closed until salinity increases, with individuals capable of surviving low levels for six weeks (Paalvast and Van der Velde 2011). Moreover, *T. navalis* has been observed surviving salinity levels as low as two PSU for 24 days (Blum 1922). Coupled with their already high tolerances, these behaviours allow shipworm to inhabit dynamic maritime environments such as estuaries, where conditions can be highly variable.

Conditions in the coastal waters around Scotland have been generally well-studied. This is particularly true for sea surface temperatures, which range seasonally from 4–18°C in the southwest, with a slightly

narrower variation of 6–14°C in the north and west (Baxter et al. 2011: 32). Despite some cooling trends recorded in recent years in UK coastal waters, long-term warming is the underlying tendency (MCCIP 2017). Although limited data has been published for salinity in coastal waters, levels of 22–35 PSU have been recorded in various locations around Scotland (Bresnan et al. 2016). However, in estuarine environments (and up to 20km from the coast), the freshwater contribution from river discharges can both have a dramatic effect on salinity and cause significant variation over short timescales of hours to weeks (Holt et al. 2010: 364). In summary, current conditions in Scottish waters do align with the requirements of these species, although they may not be optimal.

Climate change will impact these conditions: the shallow shelf seas around the UK will likely experience the effects differently than will the open ocean (Holt et al. 2010), and they already show recent evidence of warming at a faster rate than the global average (Dye et al. 2013a). Temperature increases of between 1.5–2.5°C in the northern North Sea and 2.5–4°C in other areas around Scotland have been projected by the end of the twenty-first century, with the increases largest in the autumn (Holt et al. 2010; Lowe et al. 2009: 73–74), although more recent work has suggested slightly greater levels of warming (Tinker et al. 2016).

The salinity of seawater is also changing globally. Although salinity variability has year-to-year variation (Holt et al. 2010), it is thought that areas where evaporation dominates have become more saline, while waters have become fresher where precipitation dominates (IPCC 2013). There is admittedly a greater degree of uncertainty in projections of future salinity levels. Although salinity around the UK has increased over recent decades (Dye et al. 2013b), some projections (Holt et al. 2010; Lowe et al. 2009: 77) have suggested that the surface waters of the North Sea will become marginally less saline by c.0.2 PSU by the end of the twenty-first century, and other areas will decrease by c.0.1 PSU. More recent work (Tinker et al. 2016), however, projects a greater degree of freshening, by c.0.41 PSU. Changes in salinity are linked to precipitation levels, and, since the UKCP09 projections were prepared, updated climate models have suggested that summer rainfall in England and Wales is less likely to decline (CCC 2016a:

24), with a consequent impact on salinity levels, particularly in coastal areas, where rivers have a significant influence (Holt et al. 2010: 364).

### **Potential Effects of Climate Change on Shipworm in Scotland**

These projected changes to the conditions of coastal waters around Scotland may impact the distribution of fish and other marine species, with cold species moving north and warmer species increasing in abundance or colonising new areas. Higher water temperatures in Scotland cause variations in the timing of spawning and migration, with implications for population size (CCC 2016b: 34). These impacts may also apply to shipworm populations and activity in Scottish waters. The projected warming may push temperatures above the minimum threshold for spawning and boring activity for longer seasons, increasing both population numbers and the severity of damage, as has been demonstrated in the Baltic Sea (Björdal et al. 2007). Although the WreckProtect study found no expansion of the *Teredo navalis* range, it showed that increasing autumn water temperatures extend the potential period of activity and heighten risk of attack (Björdal et al. 2007). Although salinity levels are projected to drop slightly, the extent of that drop is uncertain and small, while recent observations in the Baltic have also led to the suggestion that *T. navalis* is adapting to lower salinity levels (Borges et al. 2014). Moreover, many vulnerable sites that are naturally in sheltered estuarine locations are already subject to great variation in salinity levels, which shipworm have been shown to withstand. Furthermore, although not related to climate change, the threat may be further exacerbated by improved water quality, such as that currently being achieved on the Clyde (SEPA 2010); such improvements have been shown to positively impact the distribution of shipworm in estuaries (Paalvast and van der Velde 2011: 1828).

In summary, the current conditions in seas around Scotland provide a viable environment for some species of shipworm, which already present a threat to fragile submerged and intertidal heritage. The projected impact of climate change on Scottish coastal waters may, however, alter conditions to become more favourable for different and more damaging species, populations of which have been shown to be moving northwards (Palma and Santhakumaran 2014). These changed conditions may also be beneficial for both pop-

ulation size and activity levels of established species, increasing the threat they pose and the vulnerability of the maritime archaeological resource.

## Conclusion

The effects of climate change on Scottish coastal waters may, therefore, exacerbate the risk of damage to already vulnerable sites. Although coastal erosion, storm damage and inundation by rising sea levels are the most spoken-about effects of climate change on coastal heritage sites, the case studies presented here exemplify other challenges faced by intertidal heritage. Fragile sites in the intertidal zone are vulnerable to a host of other threats, beyond those common to all coastal sites, that are unique to their location on the shore, where they are covered by the incoming tide twice a day. As climate change alters the physical and chemical properties of coastal waters, the sites' environments will be changed in subtler, less visible ways. By creating an environment more favourable to the survival, spawning and activity of marine borers, which are well-attested to be a destructive force as regards intertidal and submerged wooden structures, climate change will compromise the condition and survival of these valuable and important remains. These threats can be extrapolated to other intertidal wooden sites around the Scottish coast, such as submerged forests and marine crannogs, which are often of archaeological significance for their rarity or research potential.

Such sites are often unrecorded and under-studied. There may be a number of reasons to account for this issue. The intertidal zone falls neither quite within the remit of terrestrial archaeology nor within the traditional domain of nautical archaeology. Past coastal surveys have not always succeeded in locating such sites, partly due to the logistical difficulties of working on the foreshore. The minimal nature of records relating to the three significant sites profiled above before we began our work, despite the fact that two were situated in areas which had already been subject to coastal surveys, emphasises the need for integrated work with local communities to identify sites, carry out repeat survey visits to monitor change and highlight threats to and record sites before they are affected. In the face of current and potentially growing climate change-induced threats



to sites' conditions and survival, there is a growing urgency to locate, survey, investigate and record this important, rare and vulnerable heritage.

## Acknowledgements

The authors would like to thank all of the volunteers across Scotland who contributed to SCHARP; and the Heritage Lottery Fund, Historic Environment Scotland, the Crown Estate and the University of St Andrews for supporting the project.

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